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Improving food security as disaster relief using intermediate moisture foods and active packaging technologies

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ABSTRACT

This study aims to present alternative solutions for food aid that meet the needs of disaster victims after significant disasters. Food support in post-disasters period is a vital humanitarian service that enables disaster victims to survive and maintain their health. Providing that, the food must have a long shelf life and be nutritious and safe. Intermediate moisture foods (IMF) are shelf-stable products and have a high potential for use in disasters. Recent developments in active packaging (AP) technologies helps to enhance the quality and extend the storage stability of food, including the IMF. This study shows that AP technologies with antimicrobial agents, oxygen and moisture absorbers can improve the storage stability of food and reduce the risk of microbial contamination. Furthermore, using these technologies in food packaging can provide sustainable alternative to conventional packaging and increase the stability of food in potential future disasters.

1. Introduction

A catastrophe or disaster (earthquake, flood, volcanic activity and tsunamis) is defined broadly as a fundamental disruption that renders the social system ineffectively (Agrawal, 2018; Perry, 2018). Rapid urbanization and ageing populations increase the complexity of disaster outcome (Tendall et al., 2015). In Turkey, according to the Disaster and Emergency Management Authority (AFAD) operating under the Ministry of the Interior (Turkey), disaster is defined as: "A natural or unnatural incident that causes economic, physical and social loss to society as a whole or specific parts of society, stops or interrupts the human activities and for which the coping capacity of the affected society becomes insufficient". A disaster is not a crisis in the traditional sense of the word - a situation in which important decisions involving risk and opportunity must be made in a specified short period of time - rather, disasters are management processes that must be maintained and management issues address major technical emergency that could result in personal injury or loss of lives (Shaluf et al., 2003). Although it is a natural incidents, earthquakes have many negative impacts ranging from affecting infrastructure, personal belongings, and ecosystems to adversely affecting the psychosocial well-being of individuals (Agrawal, 2018; Aydin, 2023).

Turkey is among the countries with the most extreme seismic activity in the world (Shafapourtehrany et al., 2022). Recently, two earthquakes (Mw 7.8 and Mw 7.7) occurred on 6 February 2023 at 04:17 am and 13:24 pm at local time, respectively (Zhang et al., 2023). Their epicenters are in the vicinity of Pazarcık and Elbistan (Kahramanmaraş) in south-central part of Turkiye. The main shocks and earthquake swarm affected 11 provinces, and more than 50 thousand people died due to old structures and substandard construction practices. Additionally, 2.273.551 people in these provinces faced food and shelter problems right after the incidents (Anonymous, 2023c). Considering the number of people were affected, a significant need for food and shelter emerged after the earthquake, due to the priority was rescue operations and the lack of perception of the size of disaster played havoc. According to the Maslow's hierarchy of needs, the system has fundamentally collapsed (Çoban, 2021). In this emergency situation food become one of the most urgent needs of the disaster victims.

Disaster relief foods (DRF) aid is the one of the main reflexes of the society towards to disaster victims. Food aid can be reviewed in two stages; first one is about gathering and sending to disaster area as quick as possible while second is about content and security of the aid that require proper handling (Jackson, 2019). Hossain et al. (2009) examined the food aid and malnutrition in children aged 6 to 59 months

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following the October 2005 Pakistan earthquake. Lusk and Andre (2017) focused on aid relief in Haiti after the earthquake occurred in 2010. Their results show the importance of site (region) specific policies. In addition to content of the food aid, the food packs distributed by various organizations must meet the daily caloric and micronutrient needs of victims who depend only on the food aid delivered after disaster (Gomez & Ignacio, 2020).

Just like previous disasters (Özcan & Ateş Duru, 2021), the earthquakes that struck on Feb. 6, 2023, in South-east of Turkey also revealed the problems in food supply to the disaster victims (Aldemir, 2023). Local press and social media posts pointed out that delay on the delivery progress caused large quantity of the food to be wasted. Lack of power supply and damaged infrastructure caused delivered food to be exposed to cold weather in Kahramanmaraş and Malatya and surroundings. In order to prevent occurrence of the problem in future earthquakes, two main conditions emerge from the long list of the disaster management applications; government and local authorities must have site-specific first aid protocols and food aid to be delivered to disaster area should have longer life span and resilient to extreme weather conditions.

The aim of this study is to present appropriate alternative solutions using DRF such as intermediate moisture foods (IMF) and various active packaging for food aid that meet the needs of disaster victims after disasters such as earthquakes.

2. Post-disaster food needs

Kottusch et al. (2009) reported that after accidents, in which victims were trapped or buried alive, the question how long one can survive without eating and drinking. This research underlined that survival time without food and drink varies within a time span of 8 to 21 days. This period includes lacking movement and semi coma stages. AFAD stated that up to 97 % of the victims were rescued by their neighbors. Thus, first rescued people act as work force and must not let their health deteriorate. Professional and voluntary rescue teams work around the time, and they also need to eat and rest therefore food supply should start as soon as the disaster occurs.

Humanitarian food aid goals to make sure enough, safe and nutritive foods before, during and after a humanitarian crisis when food consumption would otherwise be inadequate or insufficient to prevent excess mortality or acute malnutrition, which is a detrimental to survive mechanism. Food aid can be the direct provision of food. However, it can use various instruments, including the transfer or provide the relevant services, goods or inputs, vouchers or cash, knowledge or skills (Anonymous, 2004, 2013).

Food security is achieved by ensuring a safe, sufficient, adequate and appropriate food supply (Bernard de Raymond et al., 2021). Here, safe means the absence of danger, sufficient and adequate defines. both nutrients and calories, respectively, and appropriate relates to taste and ethnicity (particularly in regards to emergencies, i.e. use of readily available food) (Marsh, 2012). This is an essential policy for all countries. Food security is crucial in times of disaster. Disasters directly damage local livestock, crops and infrastructure, while severely disrupting supply chains and trade at the national or international level. Food security is a complex topic with multiple social, political, financial, environmental and drivers that include parts of food availability, access and use (Cisneros-Garcia et al., 2023). The Centers for Disease Control (CDC) recognizes that food supplies may be interrupted at any time during a disaster, and therefore recommends that at least three days' supply of foods that have the following features be kept in stock (Anonymous, 2019);

- Long shelf life,
- Requires little or no cooking, water, or refrigeration during downtime,
- Meets the needs of young children or other family members who require special diets,
- Meets the needs of pets,
- Not too salty or spicy (since these foods will increase the need for drinking water).

The requirements for food packaging performance are constantly increasing and new distribution opportunities are emerging so that next-generation packaging technologies can effectively bring marketable and economical solutions to the food business (Werner et al., 2017). The increased food protection with packaging provides ultimate potential to improve global food security. It is impossible for any food processing to be effective unless suitable packaging protection is used. Natural, dried, fermented and processed foods require proper packaging and protection for long lasting shelf life. Packaging that extends shelf life helps preserve nutrients and gives you more time to transport to remote areas. Ideal packaging for foods that require low gas permeability (oxygen and moisture) act as a barrier. This makes them an essential part of both food safety and food safety adequacy. The global promotion of food safety and security is significant for suppliers of processing and packaging materials, especially with active packaging (Marsh, 2012). Active packaging could significantly improve the food safety.

Post-disaster rations and emergency food are high in carbohydrates and focused on providing energies to survivors. As a rule, such foodstuffs have a long storage stability (non-perishable). Nutrient-rich and fresh foods, however, only have a limited storage stability. Though intended for short-term interventions lasting a few days, aftershock work across the world, including Indonesia, Haiti, Nepal and Japan, has shown that survivors remained dependent on emergency food over the medium (days to weeks) to long (months) term, depending on the location and size or degree of the disaster. In some areas, pre-earthquake disasters resulted in ration cuts, exacerbating nutrient shortages. To make situations worse, the earthquake damaged the leading industrial supplier of dietary supplements. Therefore, lack of proper nutrition over a longer period of time can cause several health complications (Sioen et al., 2017).

Specialized foods that meet carbohydrate and nutrient sources that are easy to consume and practical to distribute should be available for disaster victims (Pandin et al., 2022). For emergency food products used after natural disasters, response plans should consider features such as emergency formulas and food items, prices, packaging, food variety, cultural norms and food safety (Ainehvand et al., 2019).

The golden hours are conducted in the disaster area and cover the nutrition activities within first 72 h. During the golden hours, it is recommended to prepare readily available products that do not require preparation and can be distributed to the disaster victims. An emergency nutrition kit may contain 250 ml water, a sweet biscuit and 200 ml fruit juice. Afterwards, the nutritional needs of the people can be met by distributing rations. These rations can include bread, fruit, bar and drinking water. After the golden hours, hot food service should be started, and at this stage, products that are easy to supply and do not spoil quickly should be preferred. In the meantime, people with special nutritional needs should also be considered (Güden & Borlu, 2023). For this reason, products with high nutritional value that do not spoil quickly in the first hours should be delivered to the disaster areas quickly (Fig. 1).

2.1. Food types for disaster victims

Primarily nutrition should be considered, and to accomplish this, various materials should be supplied in food pouches, which in turn contain individual packets of high in protein (dairy, meat, soy, pulse and fish), high in fiber and vitamin (dried vegetables and fruit). Innovative foods targeting the disaster region should also consider nutritional aspects, considering the mix of the high protein, the high fiber and vitamin and carbohydrates and oils (grains, cereals and nuts) can help reach the goal. Due to its low water activity, this food is a perfect disaster recovery option due to its long storage stability without refrigeration. Popcorn is

Fig. 1. Pictures taken in the centre of Adıyaman city after the earthquake (Aydin, 2023).

an excellent choice for providing corn nutrients that can be fortified by coating the flakes with various liquid concoctions such as fruit concentrates and caramel that can be added to the unpopped corn kernels and retained in the flakes. Crystallized-fruits like apples, apricots, pineapples, plums, peaches, pears and melons are a durable alternative to supply vitamins and especially energy when fed with dried vegetables like beans, carrots etc. Grains such as wheat, beans, etc. can also be part of a supportive diet during disasters, provided there is a minimum infrastructure and water and heat supplies to include them in the diet. Cold meats such as salami, cured ham, and dried and smoked fish are perfect solution in disaster zones because protein sources can be preserved for longer periods without refrigeration. Dairy products such as whole milk powder, skim milk and dry cheese may also be included. In addition, chocolate (powder or bar) and honey are the finest sources of energy, as well as other nutrients such as vitamins and minerals. Candies and powdered or molded sugar can be provided as a self-sustaining energy source. Roasted potatoes and roasted nuts are other excellent sources of quality proteins and oils and include nuts and cashews, almonds, pistachios etc. Majority of the above foods are in the glass state and are home-made goods preserve. Preserved and non-thermally processed foods such as meat, vegetables and fruits are also ideal for supplying food to vulnerable population groups (Cisneros-Garcia et al., 2023). The emergency/survival biscuits offer enough protein and calories to sustain and energize the body in emergency situations or strenuous activities. The product with high calorific value and **enriched with vitamins and minerals** produced by the Eti company for natural disasters and disaster relief instant high energy compressed biscuit and cookies are shown in Fig. 2. The compressed biscuits have the characteristics of non-absorbent softness, high energy, rich nutrition, anti-fatigue and rapid recovery of physical strength and includes baked wheat flour, sugar, soy protein concentrate, partially hydrogenated soybean oil, malt extract, minerals, amino acids and vitamins. Due to the expansion of high temperature and high-pressure sterilization, suitable for long-term storage and transportation, plastic bag packaging is both sanitary and practical, suitable for military and civilian use. It also has a firm consistency and tends to make you feel full after eating. Compressed biscuits are a high-calorie, vitamin-fortified, compact, compressed and dry emergency food item (food bar) that is widely used by aid organizations to provide emergency feeding to refugees and internally displaced people (Anonymous, 2023a, b).

In addition, some inventions are patented for use in disasters, such as a rice-based instant food products that can be cooked quickly by simply pouring hot water and then waiting for a while, or by simply pouring water and heated with any way will be enough to prepare. An instant dry food comprising two or more components that is rapidly rehydrated by the addition of warm water and is thereby ready to serve in a very short time (Cisneros-Garcia et al., 2023).

2.2. *Problems with food supply*

When it comes to food aid and assistance, stockpiling brings with it a multitude of complexities. The perishability of food products is an obvious challenge that requires a specialized strategy. In addition, the diverse nutritional requirements of different population groups, dietary diversity, and diversity in people's cultural and traditional dietary habits are some other the preparation challenges associated with food aid (Guleria et al., 2022).

In the post-earthquake period, the food aid supply to the affected people comes from both abroad and within the country. However, foodstuffs sent from abroad may not suitable for the religious beliefs of the inhabitants (such as pork-containing products sent to Muslim or Jewish communities). Also, the labels of the incoming products should be in their language or at least in English, so that the contents and/or usage of the products should be understood easily. These situations cause hesitation in consumption, and in turn, cause a loss of time, which is very important during the disaster (Habibzadeh et al., 2008). For this reason, having specific protocols for incoming food aid according to sensitivities of the country and requiring at least the translation of the label information of the products to be accepted will ensure that the aid reaches those in need quickly and effectively.

Infants and children in emergency areas should be prioritized for nutritional assistance in the preliminary period, and chronic disease patients in the medium and long term. It was also essential to provide continued assistance in the medium and long term for the elderly, whose needs do not diminish over time (Tsuboyama-Kasaoka et al., 2021). When the infrastructure is severely damaged, the electricity system collapses in times of disaster, and access to clean water becomes difficult. So, the food to be delivered to those in need should be products that do not spoil quickly and do not require refrigeration until the power supply is restored. Therefore, the product with less water needs and

Fig. 2. Emergency/Survival Food Biscuits and cookies (Anonymous, 2023a, b).

intermediate moisture should be preferred. In addition, some innovative products can be preferred in this context. Examples include powdered products that can be easily prepared with hot or cold water and meet the nutritional needs of a person (Cisneros-Garcia et al., 2023). However, although such products meet nutritional needs, they do not fulfil psychological needs. as an example Şimşek et al. (2019) stated that foods such as fresh fruit offered to disaster victims can improve people's well-being.

It is tough to provide products such as meat products, fruit and vegetables and dairy products to those in need due to infrastructure deficiencies in times of disaster. In this context, IMF (semi-dried) and active packaging technology can be an essential alternative in eliminating the existing disadvantages by increasing the storage stability of the food products. As access to nutrients has proven difficulty during disasters, alternative sources of nutrients need to be explored and better understood. For the food industry, producing IMF with properties similar to fresh produce while extending shelf life to meet consumer demand is critical. IMF maintains specific initial characteristics of fresh foods with high nutritional value, ready-to-eat preparation (RTE) and product safety.

3. Intermediate moisture foods (IMF)

The fruit, vegetables and meats are essential nutrients for human. However, most of these foods are highly perishable due to their high-water content. Generally, reducing water amount and water activity (a_w) values below 0.6–0.8 has been considered sufficient to reach long storability times without a cold chain (Barbosa-Cánovas et al., 2003).

Food spoilage is caused by the activity of microorganisms and enzymes in free water (high a_w values; >0.85). IMF preserves the properties of foods, such as appearance, taste, and texture. They are also preferred due to their microbial safety, high nutritional value and readiness for consumption. IMFs have a 20–50 % moisture content, and a_w values vary between 0.70–0.85. Due to these properties, IMF is microbiologically stable at room temperature (Qiu et al., 2019).

An example of IMF is 'Pastırma' (cured spiced beef) which is a traditional Turkish food. Pastırma is one of the meat products in the cured, dried, intermediate moisture food covered with fenugreek, unlike its counterparts. During the curing and drying stages of pastırma production, the water activity is reduced to 0.85–0.90. A meat product containing a more reliable microbial environment is obtained. In addition to the water activity factor, microbial suppressants such as nitrate, garlic, spices and pH effectively prevent the development of undesirable microorganisms (Dışhan et al., 2021). Another example is Biltong, a meat snack from South Africa, made by salting, flavoring, and drying thin slices of lean meat. The product does not require any heat or extra processing, and it has a water content ranging from 15 % to 50 % and a water activity between 0.60 and 0.85. The best cuts for making biltong are the tender parts from young and lean beef carcasses (Strydom, 2022). These cuts contain high protein. However, they are high in salt, which causes water demand and increases consumption of water. Thus, any food product, which is intended use as DRF should meet with all aspects and advantages and disadvantages should be considered together.

As a carbohydrate source, cakes and bread are considered to be medium-moisture foods, with moisture generally between 18 % and 25 % for cakes and 35–42 % for bread. Such products can be modified to produce DRF on an industrial scale (Day, 2016).

The traditional method used in IMF production is to dry with hot air circulation or to keep under the sun light. Although this method is cheap, it prolongs the drying time. In addition, it may cause adverse effects on the product's properties, such as browning and forming bad odor. Therefore, it is essential to use more innovative drying techniques to rid of the disadvantages of conventional techniques. Microwave, vacuum, irradiation, and freeze drying can be examples of these techniques. Although these methods preserve the physical and chemical properties of the product, they also have disadvantages such as excessive cost and difficulty of employing on an industrial scale. Innovative methods are schematized in Fig. 3 (Qiu et al., 2019).

In a study focused on the nutrition of astronauts during space travel, it was stated that when the water content of fruits such as apricots, pears and peaches and meat products such as beef jerky was reduced by 15 to 20 %, microbial activity in food products was also decreased, thus the storage stability of food products was extended. It was stated that a fixed amount of water due to sugar or salt remains in the food products, this preserved the texture and improved the acceptance of the food by the crew (Kumar & Gaikwad, 2023).

Due to its moisture content and water activity, IMF does not provide a suitable environment for bacterial growth. At the same time, molds and yeasts will find a chance to survive in the existing environment. Therefore, antimicrobial active packaging for IMF has the potential to offer a satisfactory solution. For example, an intelligent packaging matrix using ZnO nanoparticles has been shown to inhibit the existing flora from 7 logs to zero. Additionally, with increasing food safety concerns, thermal proses (pasteurization) can be an efficient alternative to provide the food safety of pre-packaged IMF. Water activity reducers are often used to prepare fruit and vegetable or meat products with instant moisture content for longer storage stability (Qiu et al., 2019).

IMF foods are preserved foods that have long shelf life when stored in proper packaging systems. Foods prepared using preservation methods are suitable for use in disaster and emergency nutrition, as their storage stability is increased through suitable control of solids-moisture interactions. Selecting appropriate and suitable packaging materials for hygroscopic food is critical to building food security resilience in the event of natural disasters. Because most dehydrated foods are hygroscopic, they tend to absorb water vapor from the environment until the water amount reaches an equilibrium state, at which point the water vapor pressure gradient between the food and the environment becomes nearly equal. Shelf stable foods in pouches can maintain their stability if their packaging provides the necessary protection (Navaratne, 2018).

The increasing request for storage-stable IMF promotes the development of packaging techniques. To protect consumers from foodborne

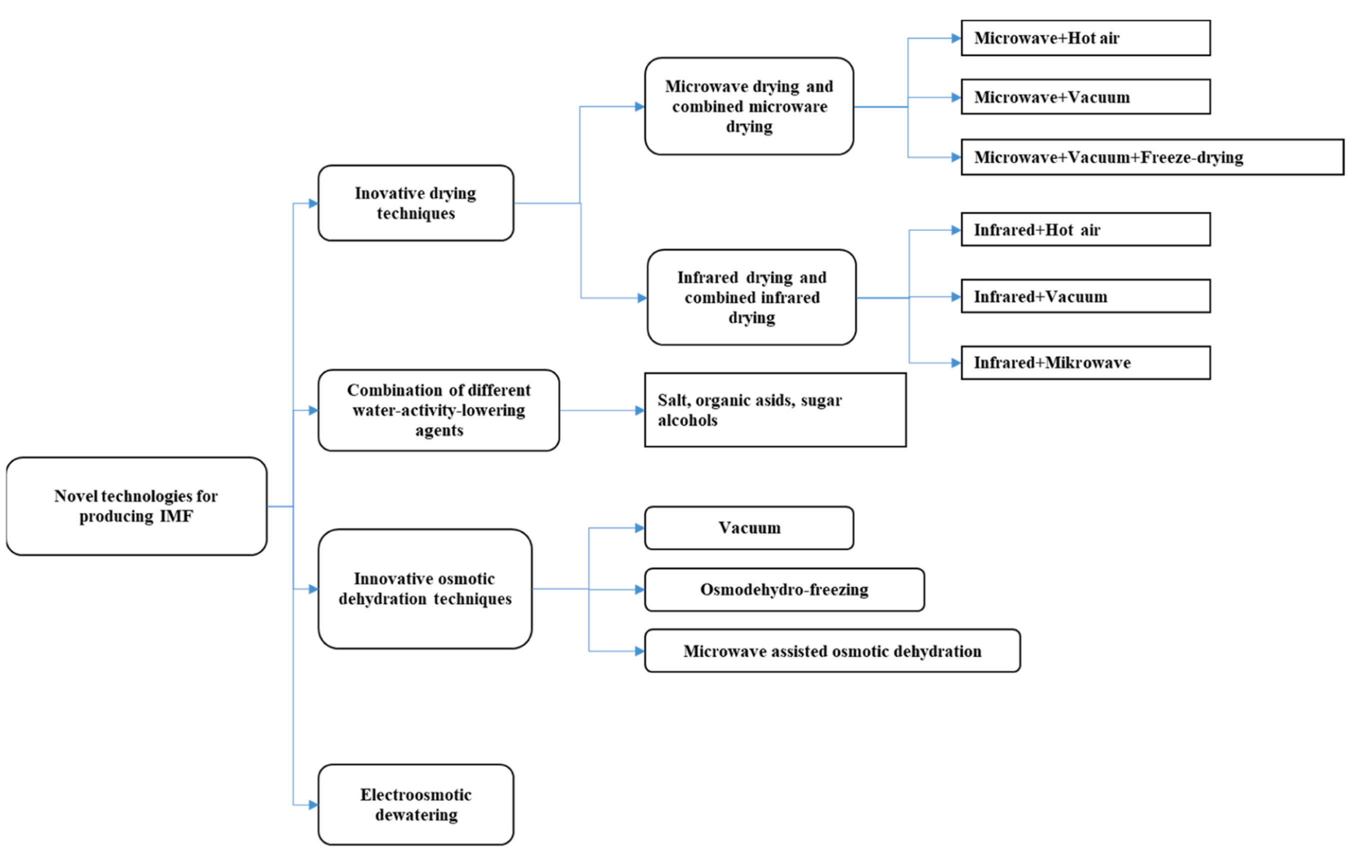

Fig. 3. Innovative methods in the production technology of intermediate moisture foods (Qiu et al., 2019).

diseases, microbial inhibition has been a key consideration in the development of new packaging. Long storage stability can be reached through modified atmosphere packaging and active packaging.

4. Active packaging (AP)

AP can be described as packaging in which auxiliary ingredients are intentionally included in or on the packaging materials or packaging headspace to improve the packaging system's performance to increase the food's shelf life (Day, 2008).

Moisture scavengers, ethylene scavengers, oxygen scavengers, edible films/coatings, flavor and odor absorbers/releasers, and antimicrobial and antioxidant packaging technologies are among the topics of AP (Prasad & Kochhar, 2014). Controlling excess moisture content in headspace of the food package is essential to prevent product deterioration especially microbial growth and enhance its shelf-life with high quality and safety. Excessive water formation inside the food package occurs due to the respiration of fresh products, temperature fluctuations in the packages with high equilibrium relative humidity, or tissue fluid leakage from products. Excessive water accumulation inside the packaging promotes the growth of bacteria and mould, resulting in loss of quality and reduced shelf life. Moisture scavengers such as natural clays, silica gel, (e.g., zeolite), calcium chloride, calcium oxide and modified starch control water accumulation in food packaging. Silica gel, in particular, is the most widely used substance because it is non-toxic and non-corrosive (Ozdemir & Floros, 2004).

Fruits are perishable foods. Ethylene is a hormone that accelerates respiration and metabolism and provides fruit ripening. The ethylene at 1μL/L is sufficient for the ripening of foods. Ethylene scavengers preserve food and beverages through 3 different mechanisms (inhibition, absorption, and oxidation). Examples of these are ethylene inhibitors (1-MCP), ethylene catalytic oxidants (KMnO4, Ozone, TiO_2 etc.) and ethylene absorbers (zeolites) (Wang & Ajji, 2022).

Limiting oxygen in product packaging reduces the growth of aerobic microorganisms, restricts the breakdown of nutrients and color by oxygen and slows down spoilage by controlling the onset of oxidation, thus helping to extend the storage stability of food products (Goddard & Herskovitz, 2020). Iron powder and ascorbic acid in sachet are the most used oxygen scavengers in the AP. In addition, using barrier films such as EVOH can reduce the oxygen permeability of the packaging, giving the product a longer shelf life (Bodbodak & Rafiee, 2016).

Antimicrobial packaging can be described as a packaging system that include active components to the packaging system and/or uses active functional polymers to inhibit or kill spoilage and pathogenic microorganisms involved in the contamination of foods. Antimicrobial AP provides a controlled release of antimicrobial substances so that the concentration on the product's surface is above the target microorganisms' minimum inhibitory concentration. In order to achieve this, the selection of suitable packaging materials and suitable antimicrobial agents with structural compatibility is essential. Antimicrobial agents should be selected from intermediate polarity (hydrophilic/hydrophobic) materials that do not strongly interact with the packaging materials during packaging or are not rapidly released from the packaging materials by repulsion (Bodbodak & Rafiee, 2016). The most used antimicrobial agent in this system is silver. Chitosan with essential oils (EO) are also widely used (Carpena et al., 2021).

A study has shown that sodium-caseinate films can be an effective carrier for *Lactobacillus sakei* used as a competitive culture. It was shown that adding these bacteria to the sodium-caseinate film matrix did not change any of the physicochemical properties of the films and that the antimicrobial active films maintained their activity at room temperature (Gialamas et al., 2010). It was stated that the use of antimicrobial peptides or nanoparticles used in AP helps to prevent undesirable taste and colour changes in food and also contributes to the storage stability of food products with controlled release performance over a long period to enhance the quality of food under observation (Chawla et al., 2021).

Antimicrobial packaging technologies have properties that reduce health risks and enhance the safety and quality of foods by reducing or inhibiting microbial growth, particularly in perishable foods. However, some challenges remain in the development of antimicrobial AP, such as controlling the release of antimicrobial substances and developing packaging materials with high mechanical & transparency strength and barrier properties, that can be manufactured at reasonable cost (Motelica et al., 2020; Mousavi Khaneghah et al., 2018).

Edible films and coatings are thin layers that surround or cover foodstuffs. They control the permeability of gases (H_2O, O_2, and CO_2) to maintain the quality of the foodstuff and can also provide antimicrobial properties. Edible films and coatings comprise food-grade bio-macromolecules such as polysaccharides and polypeptides derived from renewable and/or biodegradable natural resources instead of petroleum-derived polymers (Diaz-Montes & Castro-Munoz, 2021; Otoni et al., 2017).

In general, recent studies have focused on the search for new natural and/or harmless antimicrobial compounds that are more effective and durable than antimicrobials, such as sorbic acid used in AP technology (Dıblan & Kaya, 2018). For example, Polyvinyl Alcohol/starch films containing ethyl lauroyl arginate are an AP material that can protect food quality and extend shelf life effectively (Wu et al., 2021). Another study shows that LDPE/PGL (low-density polyethylene/pyrogallol) films showed good antimicrobial activity against gram-positive and gram-negative bacteria. Due to their enhanced barrier properties and their antimicrobial activity, LDPE/PGL films can be suitable for versatile antimicrobial food packaging (Gaikwad et al., 2018). Ricotta cheese and fresh meat are easily perishable foods. As a result of a study related to these products, they demonstrated the potential applicability of polyethylene terephthalate (PET) functionalized with the formerly characterized antimicrobial peptide mitochondrial-targeted peptide-1 materials as non-cytotoxic and safe active antimicrobial packaging by inhibiting the development of spoilage microorganisms (Gogliettino et al., 2019).

Another study was implemented on ready-to-eat (RTE) roast beef. A coating solution was prepared using 5 % chitosan that was solved in acetic, lactic and levulinic acids solution in that each of them contained a 2 % ratio in the acid solution. In the study, RTE roast beef was inoculated with *Listeria monocytogenes* and stored performance at +4 °C was evaluated. In conclusion, it is shown that there is no *Listeria monocytogenes* growth in storage during 30 days (Wang et al., 2015; Ruiz Morales & Montero-Prado, 2022).

Although AP has a significant potential to increase the storage stability of products, there are difficulties in transferring the developed technologies to the industry. In addition, all studies on perishable foods are conducted at refrigerator temperature. To increase the usability of this packaging method in times of disaster, there is a need for studies that include evaluating the performance of anti-microbial packaging on perishable foods at room temperature.

The innovative food packages were limited to canned goods, pasta, coffee, rice and crackers that required water and preparation. The lightweight food packaging has a shelf life of at least one year. The right packaging also plays a crucial role in increasing the storage stability of the fresh foods; By using the AP technology, the storage stability of the fresh products can be extended from days to months. The active food packaging can also help ensure food security and build resilience to natural disasters. Improving food quality through AP of agricultural products will help reduce food waste after natural disasters (Mayuga, 2019).

4.1. Controlling IMF using AP

The amount of water in food affects how it looks, tastes, and nourishes us and how long it stays fresh and safe to eat. The rate of chemical reactions that can spoil food, such as fat going rancid, microbial growth, and colour changing, depends on the water level in the food. Losing water can also mean losing money for foods sold by their weight, like fruits and vegetables. Good packaging can help stabilise the water level in food and make it last longer. Water can get in or out of packaged food through holes or cracks in the package or pass through the packaging material itself. Packaged foods exposed to humid air or liquid need a protective layer outside the package to ensure moisture resistance and structural integrity (Sand, 2021).

Matan et al. (2006) stated that gas in the volatile phase of cinnamon and clove oil demonstrated the ability to inhibit spoilage fungi, yeast and bacteria normally found on IMF when used in a 1:1 ratio at 4000 L in a modified atmosphere.

Singh et al. (2020) studied starch-based edible films incorporated with blueberry pomace powder. It is shown that the film has a better water vapour transmission rate than conventional polyethylene films. Because of the high-water solubility of starch films, it is indicated that starch-based films are convenient for IMF. Coaxial electrospinning was also used in another study to encapsulate cinnamaldehyde, limonene and eugenol in the core of nanofibers to improve the functional properties of fish gelatin mats. Results showed that nanofiber mats exhibited potent antifungal activity compared to *Aspergillus niger*. The nanofiber mats provided adequate control against microbial spoilage of wheat bread stored under ambient conditions for ten days. It showed that the developed nanofiber mats could potentially be suitable as AP for foods with low to medium moisture content (Mahmood et al., 2023; Othman et al., 2022) (Table 1).

Table 1
Functions of active packaging on several foods (Ruiz Morales & Montero-Prado, 2022).

Scavenger function	Action	Food application	Component
Antioxidant	Control of the increase in oxygen radicals	Cashew fruits	Mango leaf extract
	Enzymatic and non-enzymatic browning	Fresh cut apples	Sodium metabisulfite
	Fat oxidation	Fresh chicken meat	Aloe vera
		Beef	Oregano and rosemary essential oil
		Fresh meat	Flaxseed, ginger, grape seed, and rosemary essential oil
Oxygen absorbers	Oxygen scavengers	Beef jerky	Polyisopropene
		Ham cut into slices.	Palladium
CO_2 absorbers	Reactivity with CO_2	Fresh strawberries	EMCO-A and EMCO-B
		Kimchi	Calcium hydroxide with activated carbon
		Fresh meat packaged	Sodium carbonate
Ethylene absorbers	Reactivity with ethylene	Cherry tomatoes	$KMnO_4$
		Mushroom	1-MCP, $KMnO_4$ and cinnamon
		Tomato	Chitosan and titanium dioxide nanocomposite
Antifungal and antibacterial	Antifungal and antibacterial activity	Sliced cooked ham	Green tea extract and oregano
		Largemouth bass	Anthocyanin
		Oyster mushroom	Pulverised pomegranate peel
		Fresh strawberries	Ethyl formate
		Apples	Palmarose and star anise
		Kimchi	Calcium hydroxide with activated carbon
		Fresh meat packaged	Sodium carbonate

IMFs are foods that have low water activity. Although low water activity protects the IMFs against microbial spoilage, yeast and moulds can survive on the surface of the IMFs. So antimicrobial AP is essential from this aspect. In addition, because of the low moisture content of IMFs, these foods can absorb moisture from the environment. With increasing water content, IMFs become more prone to microbial spoilage. Using the AP containing moisture scavengers that reduce water accumulation in packaging or films that ensure arrangeable water permeability can extend the shelf life of IMFs. Functions and components of studied films in literature are shown in Table 2 that can be used in IMF.

5. Impact of disasters on the world food sector

The losses caused by disasters are shown in Fig. 4. According to FAO statistics, 58 million hectares of crops were damaged due to disasters between 2003 and 2013 and about 11 million of livestock were lost value of nearly USD 11 billion (Anonymous, 2015).

Disaster risk reduction measures are needed to reduce, prevent and mitigate the significant impacts of disasters on people and agriculture, which are a significant part of their lives. Agricultural productivity and growth depend on food production systems that are resilient to harvest losses due to climate variability and shocks. This requires a strong emphasis on the management and more sustainable use of vital resources such as water, nutrients, genetic resources and soil, along with sector-specific disaster risk reduction policies, practices and technologies. Recognizing the critical importance of agricultural resilience for food security and nutrition. It was recognized that risk reduction measures need to be implemented more broadly, as the damage and losses caused by agricultural disasters jeopardize sectoral development goals for growth and productivity and prevent national goals from achieving food security (Anonymous, 2015; Bendimerad, 2003).

Understandably, natural disasters affect the food supply chain at all levels, starting with agriculture. When a disaster occurs, the agricultural industry's physical damage directly affects the supply chain (OECD/-FAO, 2016).

6. Conclusion

Food security is essential in ensuring people can access the food they need. With the proper measures, one can ensure that the food they need is safe and of the highest quality. With high carbohydrate, calcium, and fiber content, IMF can meet human nutritional needs during emergencies or disaster. In this respect, IMFs are excellent alternatives that can minimize health risks, have high nutritional value and have a long shelf-life in disaster situations. The AP technologies have also the positive impact on food safety and shelf life in disaster situations. The production steps of these foods can optimize essential factors such as water activity and moisture control while providing adequate nutritional value. The reducing moisture content can prevent food spoilage by inhibiting microorganism growth and reducing health risks. In addition, IMFs can also be advantageous in terms of energy density and portability, which can facilitate transport and distribution in disaster areas.

The study underlined that the active packaging components with antimicrobial properties, oxygen absorption and moisture control can enhance the storage stability of foods and reduce the risk of microbial contamination and proliferation. The active food packaging is also suitable for ensuring food safety and building resilience against the natural disasters. When producing food for natural or provoked disasters, it is important that supplies are appropriate for the nature of the disaster, and sophisticated products should be kept to a minimum to facilitate large-scale preparation and consumption.

It is concluded that using IMFs combined with AP technologies to deliver food aid in disasters is a better option for improving high nutritional value in food aid quality and stability against natural

Table 2
Water barrier and antimicrobial films.

Function	Film Component	Food application	Results	Reference
Water barrier and antimicrobial	Citrus pectin incorporated with clove bud essential oil	In vitro	The inclusion of clove bud essential oil (0.5 %, 1.0 %, and 1.5 %) significantly enhanced the water barrier properties of the films	(Nisar et al., 2018)
Water barrier and antimicrobial	Pectin film incorporated with the marjoram essential oil encapsulated with Pickering emulsions.	In vitro	The films containing pickering emulsions had good mechanical and water barrier properties.	(Almasi et al., 2020)
Water barrier and antimicrobial	Glycerol-plasticized cassava starch incorporated with 2 % pectin and 1 % lemongrass essential oil	In vitro	Emulsification (Lemongrass essential oil with Tween 80) improved thermal stability, barrier to moisture, and also mechanical properties.	(Mendes et al., 2020)
Water barrier and antimicrobial	Gelatine-based nanocomposite containing chitosan nanofiber and ZnO nanoparticles	In vitro	The nanocomposite showed high mechanical and water barrier properties. In addition, ZnONPs improved the antibacterial activity.	(Amjadi et al., 2019)
Water barrier	Low-density polyethylene/chitosan/basil-oil	Chicken breast	Chitosan-basil oil active packaging films exhibited enhanced tensile, barrier, and antioxidant properties.	(Giannakas et al., 2021)
Water barrier and antimicrobial	Cinnamon leaf essential oil (CLE, 0.75 %, 1.00 %, and 1.25 %) was incorporated into the Bombacaceae gum films	fresh salmon fillets	The bioactive bombacaceae gum films exhibited antimicrobial activities against the tested pathogenic bacteria. The films showed decrease in its tensile strength, whereas water barrier properties increased.	(Cao and Song, 2020)
Water barrier	Kaolin and silver-kaolin in gelatine-composite film	In vitro	The addition of kaolin in gelatin films lower water vapour permeability. By incorporating these two materials, films have great antimicrobial effect towards both Gram-positive and Gram-negative bacteria.	(Nur Amila Najwa et al., 2020)
Water barrier and antimicrobial	Poly vinyl alcohol/ethyl cellulose/tea polyphenol nanofibrous films	Pork	Water vapour permeability was reduced from 0.71 to 0.42 g·mm/m^2·h·kPa. Meanwhile, these composite nanofibrous films exhibited good antioxidant and antimicrobial activity.	(Yang et al., 2021)
Water barrier and antimicrobial	sodium-alginate /glycerol/thymol/natural zeolite film	Soft cheese	The nanocomposite film exhibited enhanced, mechanical properties, oxygen and water barrier, antioxidant and antimicrobial activity, and it is capable of extending food shelf-life.	(Giannakas et al., 2022)
Water barrier and antifungal	The alginate-based edible film incorporated probiotic bacterial cells (viable and non-viable Lactiplantibacillus plantarum IS-10,506).	In vitro	Alg film performance exhibited enhanced the water barrier property. Alg-L film may have potential applications for protecting food products from light, and fungal decay.	(Wardana et al., 2022)
Water barrier and antimicrobial	ZnO/plant polyphenols /cellulose/polyvinyl alcohol	In vitro	The ZnO, enabling it to function as an antibacterial and UV shielding agent. ZnPCP−10, blocked almost 100 % of UV and visible light. Meanwhile, it also had good antibacterial activity against E. coli and S. aureus.	(Song et al., 2023)

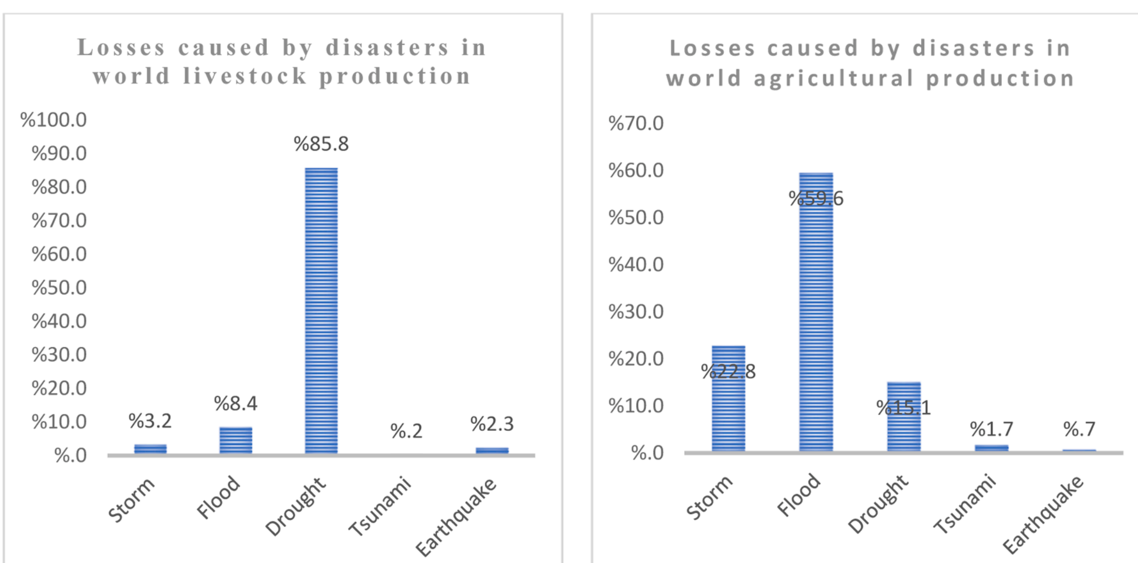

Fig. 4. Distribution of agricultural and livestock losses caused by disasters (Anonymous, 2015).

calamities. The available information can be an essential guideline for decision-makers in planning and distributing food aids. For future research, especially evaluating the performance of the AP at ambient temperature is recommended. Countries that have risk management plans in place during unstable times such as disasters will be better able to respond in the short term, which of course will result in improved food safety and hence a reduction in losses and damage to infrastructure across the country.

Ethical statement - Studies in humans and animals

There are no human subjects in this article and informed consent is no applicable.

Ethical statement

This work does not involve trials on any human or animals.

CRediT authorship contribution statement

Alper Aydın: Writing – original draft, Methodology, Investigation, Formal analysis. **Muhammed Yüceer:** Writing – review & editing, Writing – original draft, Visualization, Resources, Project administration, Methodology, Investigation, Formal analysis. **Emin Uğur Ulugergerli:** Writing – review & editing, Formal analysis. **Cengiz Caner:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation.

Declaration of Competing Interest

The authors declare no conflict of interest

Data Availability

Data will be made available on request.

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